THE

PROGRESS

OF THE

Metallurgy of Gold and Silver

IN THE

UNITED STATES,

By T. EGLESTON, Ph.D.

From Vol. III, School of Mines Quarterly.

NEW YORK, 1882.

ERRATA.

Page 40. line 17. for, in the last number of the Quarterly, p. 80, read p. 10.

THE PROGRESS OF THE METALLURGY OF GOLD AND SILVER IN THE UNITED STATES.

BY T. EGLESTON, PH.D.

THE progress of metallurgy in the United States during the last thirty years has not only been very rapid, but has produced very extraordinary results. Previous to the discovery of gold in California in 1848, the United States produced but a small portion of the world's product of metals, and its people were not known as skilled in the mining or metallurgical sciences. The great coal-fields were known and worked, and iron was produced in what would now be considered very small quantities. The discovery of copper on the upper peninsula of Lake Superior, and of gold in California, showed the want of knowledge of these subjects amongst our people, and undoubtedly gave the stimulus to the energy and enterprise which now makes the United States one of the greatest of mining and metallurgical nations. Twenty-five years ago there was no place in the United States where an elementary knowledge of either mining or metallurgy could be had in any of the educational institutions of the country. To-day a more thorough knowledge of these sciences can be had here than anywhere else. The prospector of these early days has been obliged to give way to the thoroughly trained mining and metallurgical engineer. No finer or better

examples of what skill and science can do are to be found than the works which have been erected in different sections of the United States within the last fifteen years. In the early days, when prospectors and mineral wands were more or less relied on, "science," which meant education in general, was looked on with suspicion; the demand was for "practical men." But as soon as it became apparent that there was enormous wealth in the ground which could not be extracted by half-educated men with empirical means, science was called in. In the first few years the "scientific cuss," as he was called, was expected to be a mining, metallurgical, mechanical, and chemical engineer, and in all cases where he did not know, to improvise his knowledge; but it was not long before experts in all these branches were to be had, and, in consequence, new methods and new processes have resulted, so that mining and metallurgy have made more progress on this side of the Atlantic in the last thirty years, than had formerly been made in the Old World in more than one hundred. A quality of mind seems to have been produced by the mixture of races on this continent, which, while demanding for the people as a whole the most general information, enables us to easily grasp details, while the eminently mechanical genius of our people leads us to adapt, improve, and invent machinery for every purpose, and thus, by replacing hand labor, to both improve and cheapen the cost of processes.

The gold excitement in 1848 was produced by the discovery of the very rich placer mines on Sutter Creek, Amador Co., California, from which the gold in quite large pieces was easily separated by washing with water in a common pan. Shortly after, the discovery of a number of nuggets of large size,[1] and

[1] A list of the large nuggets is not without interest. One of 3000 lbs. was reported to have been found in the West Indies and sent to Spain in a ship which never reached its destination.

NUGGETS FROM AUSTRALIA.

Sarah Sands, 1850 (?)	223 lbs.	4 oz.
Ballarat, 1853	184 "	8 "
" " "	135 "	
Blanche Barkley, 1842 (?)	146 "	6 "
Two, 1849	112 "	
One, 1851	106 "	
Maryboro, 1855	88 "	4 "
Fryer's Creek, 1855	84 "	
Old Daisy Hill, 1855	73 lbs.	4 oz.
Ballarat, 1855	48 "	
Bendigo, 1852	47 "	
Ballarat, 1855	40 "	
Bendigo, 1852	28 "	4 "
Dascombe, 1852	28 "	
Mt. Blackwood, 1855	24 "	

URAL MOUNTAINS.

Near Miask, Siberia, 1842	96 lbs.
In 1878	78 "
One	27 lbs.
Several of	16 "

the rumor that others had been found and cut into small pieces to prevent their value being known, caused the wildest enthusiasm all over the United States. Some large fortunes were made among the crowd of adventurers who rushed to California, but no one can know of the misery and disappointment caused by this wholesale emigration. The success of the few was widely published, but the record of the failures was never made. What they must have been is shown by the fact that after the State of California had provided insane asylums for the percentage usual in other States, the authorities were obliged to double their capacity.[1]

So entirely has mining formed a part of the history of the country, that the very words which express the miner's joy or sorrow, his success or failure, have passed into the current conversation of society. To "strike it rich," to "find pay," to "pan out," or to "get down to hard-pan" or "to the bed-rock," indicate to the people of the Western coast their success or failure, their prosperity or adversity, more emphatically than any other words in the English language could do.

It is very doubtful whether the Western States and Territories would have been settled even now but for the fabulous yield of the early discovered surface deposits. California had been more or less occupied for two hundred years by Spaniards and Mexicans. It was known in a general way that gold was to be found either in that country or districts adjacent to it. Shallow placers had been worked with very small results for a long time. Placer gold was discovered and worked in 1841.[2] In 1843 gold-bearing quartz had been worked. But the discovery

PARAGUAY.

One of 50 lbs.

PERU.

In 1730, one of 45 lbs.

UNITED STATES.

California, Calaveras Co., 1854	160 lbs.	N. Carolina, Cabarrus Co., 1838	37 lbs.
" Sierra Co.	106 "	California, Sierra Co.	32 "
" " 1869	95½ "	" Georgetown, 1865	17 "
N. Carolina, Reed Mine	80 "	N. Carolina, Anson 1829	10 "
California, Sierra Co., 1871 (not authenticated)	64 "	California, Nevada Co.	8 "

In England several nuggets of 40 ounces have been found, but none larger. None have been found in Brazil.

[1] I have this statement from a former Treasurer of the State of California.

[2] *Engineering and Mining Journal*, vol. 32, p. 170.

of gold in the sluice of a mill depopulated, for the time being, the city of San Francisco, brought a small population from China, and thousands from Mexico; but the country was in a very few months taken possession of by men from the Eastern States, attracted there both by the fabulous stories about the gold and by their love of adventure. Everybody who could dig (and who could not?) became at once a miner. It was not an unfrequent thing, so rich were the deposits, for men who could not earn more than seventy-five cents a day where they came from, to make several hundred dollars between sunrise and sunset, with the rudest appliances, and with a loss of no one knows how much gold beside. This great gain was, however, of but little use to him, because, having acquired it without much labor, no special value was attached to it, and he spent it as freely as he found it. The price of everything in California was, consequently, very high.[1] Trade was carried on as barter, in which "gold dust," as it was called, which was of all sizes, from a nugget the size of the fist to an impalpable powder, answered the purpose of a medium of exchange. In every-day life the fine material was used in the place of coin. It was carried by the miners in buckskin bags which were opened for the merchant to take his own pay by repeatedly taking out what he could hold between his thumb and forefinger. A single pinch from the bag was considered to be equal to twenty-five cents, which was the lowest value recognized; two pinches were equivalent to fifty cents, four to one dollar, and so on. The honest (?) merchant of those days kept his forefinger pressed on a conical button in his waistcoat, in order to make a depression in it, so that the intrinsic value of the single pinch was often equal to a dollar, or even more. This was of no consequence whatever to the miner, who did not condescend to weigh his gold, except in the case of nuggets or of large payments or bank deposits.

At first, only the shallow and very rich placer mines were worked. They required no capital, and but an extremely limited amount of intelligence and skill to work them. So long as they were easily found and the pay abundant, the separation of the gold was only approximative, and no special improvement was made in the processes of extraction. If the sand was very

[1] Flour, $7.50 per pound; butter, the same; a barrel of pork, $210; a bottle of ale, $5; a candle, $3; a tin pan, $9.

rich and water was not easy to be had, it was simply winnowed in a blanket, and what the wind did not blow off was amalgamated when mercury could be procured, or it was panned in a rough way when water could be had, or was approximately picked out when there was neither water nor mercury. Any method was used without regard to loss, so long as the pay was made rich enough to transport, and could be sold by assay.

By such rude methods only a very small percentage of the gold was extracted, but it would cost trouble to get it all out, so it was left where it was. The miner was then careless of his mode of working, giving no thought to the future, and was extravagant in his habits and methods. In less than five years after its first discovery, the quantity of gold had reached a maximum, and after 1853 began to decrease steadily. As the amount of gold diminished the methods of extracting it improved; the miners became aware that they were losing gold, and little by little they ascertained that this loss occurred in several different ways: either it was not separated from the lumps of sand or clay and was carried off with them, or it was so thin in the pay rock or became so thin in the process of extraction that it was buoyed up and carried off by the water, or was lost because the gold for some reason did not amalgamate. At first he simply called this light gold "float" and the other "rusty," and made no very great account of it. But as it became evident that a very large proportion of the gold in the "pay" was being lost in this float and rusty gold, he became anxious first to ascertain how much there was that he did not catch and what part of this was float—a material so light that it was carried off upon the water, and was thus swept away—and what part was rusty, that is, did not amalgamate with the mercury. To determine this he sought for machines to work with. The miner's pan had up to this time been the tool with which he "got the color," which is the expression used when the gold begins to appear after washing the pay dirt in a pan; but when he found that he must have other appliances, the miner of 1848 took the processes which he found in use by the Mexicans and the Mexican Indians in California, and adopted them bodily. These were, the miner's pan, which he adopted when he first came into the country, and continued to use so long as the placers were very rich; the arastra, and the Chilian mill upon which so much ridicule has been cast

in later times, and to the principle of which we shall probably have to come back as the gold grows scarcer. The rude methods of concentration associated with these machines were the only methods that he found there, and these he accepted without at first thinking of any improvement.

With the altered condition of affairs every experiment that want of experience or an active imagination could suggest was tried. Every man improvised himself a miner, and felt it his bounden duty to commence where Tubal-cain did, but without his intelligence. The sum of all that is left of these experiments is the sluices, riffles, and undercurrents which are still in use. They alone represent the activity and energy which in the first few years produced hundreds of failures and brought loss and disappointment, and in many cases ruin, to thousands of men. But the necessities of the case had so stimulated the active minds who brought their energies to bear on the subject that the failures were individual, as the loss of wealth of a country which no one owned was not estimated, and consequently was not felt. The country reaped the benefit of all these efforts and all the gains, and in consequence has made greater strides in the way of progress, and more improvement in thirty years than has ever been made in a century by any other nation.

It is impossible to estimate the losses which must have occurred in these early days by such rough methods of working. The "Forty-niners," as they are called, cared very little whether they got out all the gold. What they did care for was to make the greatest present profit not only between the first and last of the month, but between sunrise and sunset of every day. Sunday did not count for a holiday then. It was of no consequence to the miner what he lost, but it was of great importance to him what he gained. He recognized only to-day ; he knew and cared nothing about the time when through his slovenly methods gold would become scarce, and if he knew that he was losing gold his regret was for himself because he did not get it, and not that the country was a loser. He knew nothing about political economy, and would have cared nothing for it if he had. He was extravagant in his habits, generous to a fault, careless of his methods, entirely satisfied to let the future take care of itself. By the time that the placers began to grow less productive the population of the country had increased to such an extent that, labor becoming abundant and wages so comparatively low, the necessity of living, which Talleyrand declared not to be

necessary, became a stimulus towards improvement in the processes and to the effort to save what had been previously considered as not worth saving. More careful washing made men look for a more abundant water supply. The freer use of mercury enhanced its value and set the prospectors searching for mercury mines.[1]

Our present methods, which are being constantly improved, appear extravagant to those who have been trained in the European schools, because they do not take into consideration the fact that with a rate of wages much higher than in Europe, and with transportation at its maximum, their economies would cost more to carry out than they would yield. Hence the foreigner coming to this country has generally to commence his education here by unlearning some parts of the knowledge which he has been taught to consider as his first principles, before he begins to acquire the new ideas which are essential to his successful practice among our mines and metallurgical works.

There is in this country no impediment to progress and improvement, as there is in Europe in what is known as ancient legislation, where antiquated processes have become customs, and their use precedents not to be easily set aside. Their statute books are full of laws preserving the rights of the government, of John Doe and Richard Roe, in certain specific things, and requiring in certain defined cases the following of ancient precedents or the use of obsolete processes and methods, the laws being made with reference to a condition of things which existed perhaps one hundred, three hundred, or even five hundred years ago, and remaining still unrepealed. It is undoubtedly in principle a wise precaution not to allow the investment of capital in mining enterprises without having the whole question both in a commercial and industrial point of view examined by government officers, and the government sanction given or withheld according as in the judgment of its officers it should or should not be given; but it places a great deal of power in the hands of individuals who desire to hold the leading-strings, and does away with the individuality of enterprise which is one of the chief characteristics of our nation. The anxiety to prevent the individual loss in Europe often retards the prosperity of a whole

[1] The discovery of very large deposits of the ores of mercury in California, and the original process invented there for working it, are even more remarkable than the progress made in the working of the other metals. See *Engineering* London, vol. 28. p. 239.

country, while the precedents as well as the written and unwritten laws of some of the older countries, and the system of centralization in their governments which entrusts everything belonging to the government to corps or to the heads of bureaus at the seat of government, are great impediments to progress. In this country we are at liberty to deal with the necessities of the case as they occur. The impediments to progress are not too much but too little law, not ancient but conflicting legislation. These impediments are, however, incident to any new order of things, and it will not be many years before the last of these difficulties will be removed.

When shallow placer-mining became less remunerative, the question of transportation commenced to be a factor in the question of production. While a miner was earning $100 a day, the fact that he was forced to "pack" every article he purchased for use as well as his gold on a mule to be carried for days or weeks, or concealed his treasure about his person and travelled on foot a considerable distance to invest or deposit his dust, was a matter of very little consequence in view of the large amount so easily earned.[1]

But when he was reduced to "hard-pan" and only earned a little more than was necessary for the sustenance of life, the question both of improved processes and of transportation became a very serious one, and had to be studied very carefully. At this point he either improvised himself an engineer of mines, and with ready Yankee wit devised some process which would save "the color," or transported himself and his "outfit," which in those days meant what he could carry on his back, with his pick, spade, pan, horn or spoon, or more probably all of them, to some locality which was not so far removed from civilization. Others on the contrary sought in localities farther from civilization richer pay diggings.

It was not long before this continued migration produced its results, for while the miner at first searched only for gold and worked for gold alone, when it became scarce and the necessity of living became to him imperative, translating itself into the gnawings of hunger, other things became valuable besides gold,

[1] The safety and almost impunity with which large amounts were carried about the person in the early days of California mining was owing to the rapidity with which the vigilance committees of those days executed justice, which was not only speedy but severe. There were then no lawyers to impede the progress of what was almost invariably real justice, and death was usually the penalty inflicted.

and he then stopped in his transit from one district to another in search of the precious metal to locate a silver deposit, sometimes in the shape of lead ores, but he never noticed iron or copper. It was not until long after that he made the discovery that copper ores frequently carry gold.

PLACER MINING.

The deposits of gold first worked were called placers. These were at first recognized as the dry and the wet, the dry being either ancient river deposits or recent river beds from which the water was gone. The wet placers were streams which were sometimes large rivers. In these placers the gold was within twenty feet or so of the surface. The dry placers were worked with pans and sluices; the rivers containing the wet placers were dammed and the whole of the water turned into flumes or sluices. The river mud was then sluiced. As it was impossible to keep the river bed dry, both because the dam leaked and because the surface drainage could not be kept out, large wheels called "flutter wheels" were placed in the artificial channels, which pumped the water out of the river bed and furnished a sufficient supply of it to the sluices. Such workings were hazardous and expensive, for if the stream was at all large a single freshet might wash out the dam and the flume which carried the river. To make sufficient room to work and also to get enough ground to justify the expense, the flume carrying the water of the river was never less than two hundred and fifty yards and sometimes nearly a mile long. Such works were very expensive and somewhat hazardous, but sometimes yielded a very large profit. They were constructed by companies during the early days when the miners used less engineering skill and were willing to take more risks. Very few of these river claims exist now, and this kind of mining is already a thing of the past.

As the placers grew poorer the gold was sought deeper, and it was then discovered that there were placers where the depth of the deposit was over three hundred feet, where the gold on the surface sometimes yielded only a few cents to the cubic yard, but was rich on the bed-rock, hence the name of deep placers. Only shallow or surface placers and deep placers are now recognized. It is estimated that two thirds of all the gold produced in the world is taken from placer deposits.

It is quite as impossible to form any adequate idea of the

amount of gold produced during these first periods of mining as it is to estimate the losses. No attempt was made to make any record at the time. The records of the custom-houses are the only ones made, and are necessarily imperfect; they show that between 1848 and 1854 over $350,000,000 had been recorded, but previous to that time very large sums had been carried away by those going either to Europe or to the East, either in their effects or on their persons, and while the amount carried by an individual was small, the aggregate must have been very large. In the next decade more perfect records were made, which show a gradual decrease, the highest point having been reached in 1853 when the amount recorded is $65,000,000, and the lowest $26,000,000 in 1864, the total amount for the decade being $450,000,000. The next decade to 1874 shows a product of only $220,000,000, the lowest amount reached being $17,000,000 in 1873. This rapid decrease gives a very fair idea of the amount which must have been wasted within the first seven years of the most prosperous time, when the records, tho very imperfect, give an average of $50,000,000 a year, while the year 1873, when the records were most perfect, gave only $17,000,000. From 1873 to the end of 1880 the total product of the State of California was $135,113,000; the lowest annual product being $15,000,000 in 1877, and the highest $18,000,000 in 1874. The following tables, showing the amount in each year, have been prepared for me by the Director of the Mint at Washington.

Year.	Gold in Dollars.			Year.	Gold in Dollars.		
	California.	Other States.	Total Gold.		California.	Other States.	Total Gold.
	$	$	$		$	$	$
1848	10,000,000	....	10,000,000	1865	28,500,000	24,725,000	53,225,000
1849	40,000,000	....	40,000,000	1866	25,500,000	28,000,000	53,500,000
1850	50,000,000	....	50,000,000	1867	25,000,000	26,725,000	51,725,000
1851	55,000,000	....	55,000,000	1868	22,000,000	26,000,000	48,000,000
1852	60,000,000	....	60,000,000	1869	22,500,000	27,000,000	49,500,000
1853	65,000,000	....	65,000,000	1870	25,000,000	25,000,000	50,000,000
1854	60,000,000	....	60,000,000	1871	20,000,000	23,500,000	43,500,000
1855	55,000,000	....	55,000,000	1872	19,000,000	17,000,000	36,000,000
1856	55,000,000	....	55,000,000	1873	17,000,000	19,000,000	36,000,000
1857	55,000,000	....	55,000,000	1874	18,000,000	15,490,902	33,490,902
1858	50,000,000	....	50,000,000	1875	17,000,000	16,467,856	33,467,856
1859	50,000,000	....	50,000,000	1876	17,753,000	22,176,166	39,929,166
1860	45,000,000	1,000,000	46,000,000	1877	15,000,000	31,897,390	46,897,390
1861	40,000,000	3,000,000	43,000,000	1878	15,260,000	35,946,360	51,206,360
1862	34,700,000	4,500,000	39,200,000	1879	17,600,000	21,299,858	38,899,858
1863	30,000,000	10,000,000	40,000,000	1880	17,500,000	18,500,000	36,000,000
1864	26,600,000	19,500,000	46,100,000				

It is remarkable that while up to 1860 there was almost no gold produced in the Eastern States, and that while in that year only $1,000,000 is reported, between 1860 and 1870 the amount produced gradually increased, until in 1866 it exceeded it, and only fell so as to equal it in 1870. In the next decade, from 1870 to 1880, the largest amount produced in all the other States except California was $35,946,360 in 1878, and the lowest $15,490,902 in 1874; with the exception of 1874 and 1875 the Eastern States produced more than California, and in 1878 more than double the amount produced there. The total yield of gold in the United States in the year 1880 was only $36,000,000, or less than that produced by California alone up to 1862, with the single exception of the year 1848.

It is extremely difficult to ascertain the amount of gold contained in the world, and it may be said that the best estimates from the most reliable authorities are but the merest approximations. It is supposed, however, that the entire amount of gold in existence at the present time is not over $7,000,000,000. As the value of a cubic yard of gold is $9,000,000, if all this gold were melted into one mass it would contain about 700 cubic yards, which would make a block about 25 by 25 by 31 feet, or less than the cubical contents of an ordinary small city house.

Long before the fact that the gold was decreasing became known to the miners, it was evident that some new system would have to be used to extract it. The miner's pan, a household utensil, was used not because it was the best adapted to the work, but because it was the most available. It was an exceedingly rude apparatus. It was made of sheet-iron from four to five inches deep. It was filled two thirds full of dirt, and put into a hole about one foot deep filled with water, and the contents of the pan well stirred with the hands; the pan was then taken in both hands, inclined slightly outward, and shaken so as to give a circular motion to the contents. The fine material flows in this way over the sides. When this has been done long enough, the stones are removed, any lumps of clay are broken with the hand; then depressing the outer edge, it is shaken until nearly everything but the black sand is out of the pan. This is separated by blowing. It required great skill, and gave a large loss in gold. It is now rarely used except for an assay for color, for which the shovel can also be used. The pan was used for a long time after other machines were introduced, but it soon

became necessary to have other implements. As an instrument for concentration, it was succeeded by the cradle or rocker, which was not unlike a child's cradle, whose maximum capacity was 5 to 6 cubic yards of earth a day. It required two men to work this cradle efficiently, one to rock and pour on water, and one to bring the pay dirt and the water, whose weight was at least three times that of the dirt. The pay dirt was thrown upon a screen whose object was to separate the large stones and to help to break up the clay; the purpose of the water was to take up the finely divided particles. The concentrates are then panned. A pan contains about half a cubic foot of pay dirt. A one-man rocker could concentrate from 100 to 150 pans a day, and a two-man rocker twice as much. It is a very slow machine, must always be placed near the water, no matter what the distance of the pay dirt is, and even when used with quicksilver loses a very large amount of fine gold and all the float gold.

The cradle was succeeded by the "long Tom," which for nearly two years seemed a great improvement. It consists of a rough trough or launder eighteen feet wide at the upper end and thirty feet at the lower, and twelve feet long. The lower end is terminated by a screen of iron whose edge is so high that the water does not flow over it, but drops with its contents into a trough below provided with riffle bars and mercury. The pay is thrown in at the upper end and mixed with water; what passes the screens comes in contact with the mercury and is caught, but much of the fine and all the float gold is lost, tho it is a better machine than the cradle. As many as four men can work at a Tom, but it is now rarely seen.

At the same time a puddler was used, which was a barrel cut in half or a rough wooden box six to eight feet square, and twelve inches high, with an inch and a half hole four inches from the bottom. The pay was thrown into this and broken up and mixed with the water until it was all in suspension. When the plug was removed, the thin mud was allowed to run out and the operation commenced again, and so on. The gold was collected in the bottom. The puddler never was used in this country except in small claims where water was scarce, but has been very successfully and extensively used in other countries where water was not abundant.

The next improvement was the sluice, which, altho it had been formerly used elsewhere, is as much a California invention

as if it had never been used before it was invented here. It consists of a trough or launder made of rough one and a half inch boards sawn for the purpose, and nailed together without any pretence of making them fit, as it becomes tight by the swelling of the wood and the filling up of the cracks. The sluice is composed of a series of boxes, as they are called; each box is twelve feet long, sixteen to eighteen inches wide at one end, and twenty to twenty-four at the other. The height of the sides varies from eight to twenty-four inches, according to the kind of material to be used in it. The narrow end of one box fits into the wide end of the other. The length of the sluice is estimated in boxes; it should not be less than fifty feet long, and often consists of hundreds of boxes put together supported on rough trestles. The inclination is regulated according to the necessities of the case, and is called the "grade," which always has reference to the box. It is usually eight inches for a minimum and thirty inches for a maximum in twelve feet, or the length of a box. It is generally uniform, but sometimes is made to conform somewhat to the lay of the ground. The tougher the dirt, the longer and steeper the sluice must be. With a rapid descent the dirt is also much more easily separated, but the greater is the loss in gold. The boards are not only rough on the bottom and sides, but to prevent too rapid wear, and also to help to catch the gold, strips of wood are fastened in the bottom of the box, either in the direction of its length, which is most usual, or across it. These pieces of wood are from two to four inches thick, and from four to six inches wide. When longitudinal they are six feet long, so that two sets go in a sluice. The riffles are wedged in so that they can be easily removed for a clean-up or for repairs. The bottom of each box is thus filled with a screen of rectangular cavities which are the width of the distance between the riffles, and have their length and depth. Here the quicksilver which is put in at the head of the sluice rests and catches the gold as it sinks in the more or less rapid current. The water is generally made to run two inches deep over the riffles. The pay dirt is thrown in with shovels. The first dirt, which is always poor, goes to fill up the spaces between the riffles. The water, washing over this, washes out the earth and clay, the sand and gravel, and even the stones. No mercury is added until after the sluice has been running about two hours. It is then put in at the head and finds its way down the sluice, most of it being caught not far from where it is put in, One man can throw in

from two to five cubic yards of dirt a day. The number of men that can work depends on the length of the sluice and the lay of the ground. Sometimes when the earth to be washed contains large stones, an undercurrent is used. The end of the sluice is then open. It terminates with a grating of iron bars long enough to allow all the water to pass with the fine material through the grating, but allows the stones to roll out on the ground. The whole of the water and dirt is caught in a short sluice below and discharged into one parallel with the main sluice, which is thus continued. This undercurrent, tho sometimes used with the ordinary sluice, is an indispensable part of the plant for hydraulic mining. The sluice is simple in construction and use, requires but little outlay of capital, and is very effective. Unlike the outlays usually made in mining, the whole of the plant in use can be readily taken down and transported to another claim when the first is washed out, and set up there as effectively as if it were new. There is one precaution that must be taken with it, which is that lumps of clay must not be allowed to travel along it without being broken up, for they are liable to pick up the gold as they roll and carry it off with them.

Getting the amalgam out of the sluice is called cleaning-up, and the time between one clean-up and another is called a run. The length of a run will depend on the richness of the deposit, but is usually from six days to two weeks, occasionally longer. A clean-up occupies about half a day, and is usually done on Sunday. To do this the water is allowed to run after the dirt is no longer thrown in, until it is quite clear; six or eight sets of riffle bars are then taken out at the head of the sluice, and the material washed down, while the amalgam is caught at the head of the next riffles. This is taken out. The next set of riffles are then taken out, and so on. The excess of mercury is strained from the amalgam by twisting it in a buckskin bag, and the rest is driven off by heat.

HYDRAULIC MINING.

For many years the sluice was used to work nearly the whole of the placer gold of the country, and it is still the most available way for persons of small capital to treat the shallow placer deposits. It must always be looked upon as a process of great historical interest, for out of it hydraulic mining grew, which

is one of the most marvellous achievements of modern engineering skill, to which the State of California is more indebted than to all other inventions of mining and metallurgy put together There are localities where poor, shallow placers are found, where water is scarce during most of the year, but abundant at certain seasons, and where the grades are heavy. For these placers another sluice was used, known as the ditch or ground sluice. A small ditch is cut through the placer and the water turned into it, the first object being to deepen and enlarge the ditch to the proper size. When this has been accomplished, the banks are pried into the stream. No mercury is used, but cobblestones are thrown into the bottom of the ditch so that the gold may settle between them. The effort is to concentrate the gold in the dirt and then work it up in a short board sluice.

These two methods put together were the germs of hydraulic mining now so extensively used in all parts of the world, not only for gold mining, but for the removal of dirt from other ores. It appears singular that the name of the man who really invented the most remarkable process of this century should be as lost to history as if he had never existed; but in the struggle for existence, as the shallow placers grew poorer and poorer, and the gold was found at constantly increasing depths, the man was lost sight of, while his work has now been so perfected that it is one of the marvels of the union of modern engineering skill with capital. The process of hydraulic mining was invented in the spring of the year 1852, on the Yankee Jim claim in Placer Co., California,[1] where an enterprising miner, finding that he was not making sufficient money, began working his claim with a shallow ditch in the side of a hill leading to an ordinary barrel, from the bottom of which a cowhide hose was carried and discharged by means of a tin pipe against the bank, and he thus became the father of one of the greatest of modern inventions, hydraulic mining.

There is another kind of placer which deserves notice, both because it is interesting in itself and because it has been the source of disappointment and loss to so many. This is the beach gold, which occurs between Point Mendocino in Northern California and the mouth of the Umpqua River in Southern Oregon. The cliffs along the ocean front seem to be the remains of an ancient river deposit. They contain gold, and where

[1] *Engineering*, London, Eng., vol. 24, p. 353.

washed by the waves often show the shore for miles glittering with it. It is very uncertain, however, for what appears to-day is washed away to-morrow. No dependence can be placed on finding in the morning the deposit of the day before, so that all haste is made to carry the sands which are rich enough to some safe place inland to be washed and amalgamated. The beach is very narrow, and when the waves are high they wash against the bank. The gold is washed out with the heavy sand, and as the particles are very fine, it is carried down to near the low-water mark. When the ocean is still, sands of variable richness can be collected, but the waves are often so high as to wash all the sand away to the depth sometimes of six feet, and leave the bare rocks exposed. So changing and shifting is the value of the deposit that it has to be examined every day, and the washing of the following day may sometimes be six miles from that of the previous one. Such sands as these must be very rich to make it possible to run the risk of washing them and to bear the transportation to fresh water, as salt water is of too high a specific gravity to work with, for which reason the attempt to work these deposits by dredging has not been successful. It has been proposed to bring water from a distance and turn these mines into hydraulic placers washing down the banks, and depending on them for their profit, leaving the beach sands as an accessory. The tails would not then be a question of importance, but the economic results of such an enterprise would be very doubtful.

After the introduction of sluicing either on a large or small scale, the pan, the cradle, and the rocker were very rapidly abandoned to John Chinaman, who always succeeded in living off the placers that had been abandoned by the "honest miner," who, however, never had any compunction, if he found the Chinamen were tolerably prosperous, in jumping their claims and driving poor John off to find some other place for his enterprise and cheap labor.

From hundreds of dollars a day, by a gradual decrease stretching over a period of from fifteen to twenty years, the gold became scarcer and scarcer, until now it has become necessary with improved appliances to work in the deep placers material which contains from 3 cents to $1.25 per cubic yard.[1]

[1] In the spring of 1880 I was informed by the President of the North Bloomfield Mining Company that they were now working with a profit gravel containing only three cents to the cubic yard, when only a few years ago it was considered a marvel to be able to work that which yielded ten cents.

No better evidence of the progress that has been made in the working of placer claims can be had than the comparison of the cost of working them by the older and by the more recent processes. Adopting four dollars per day as the wages of a skilled miner, the cost of working a cubic yard of gravel as given by Phillips is—

With the pan	$20 00	With the long Tom	$1 00
" " rocker	5 00	" " hydraulic process	02

In the very early days the capital required by a miner consisted of a pick, shovel, a horn and spoon and a pan, two stout hands, and a valiant heart; but as the placer mines grew poorer this capital was no longer sufficient. It can readily be understood that such capital as was required in the early days did not necessitate any permanent location nor any very high order of intelligence for its use, and hence much of the surface was dug over and simply rendered difficult to work further without extracting more than a tithe of the wealth contained in the ground, merely because the miner had no permanent interest in one spot more than another, and because his capital was entirely a rolling and not an invested one. Every man then was in business for himself, but as the gold grew scarcer, first money, and then intelligence and capital became factors in the equation, so that the capital required to work any one of these claims became larger and larger, until to-day it is estimated that the plant of the North Bloomfield Mining Company has cost not less than $3,000,000, and their works are marvels both for the originality and engineering ability displayed, consisting of dams 90 to 100 feet high, ditches, pipes, and sluices many miles in length, and every hydraulic appliance which engineering skill and capital can add to their works.

These deep placers are the deposits formed in the beds of ancient rivers which have since been so covered by recent accumulations, or cut across by modern valleys of erosion that without a careful survey no one could recognize table-lands twenty miles distant as part of the same ancient river deposit. In some cases the gold-bearing material has been covered by beds of basalt one hundred and fifty feet thick.[1] In many cases the erosion

[1] A map of the basalt-capped deposits of the North Bloomfield Co. is given in the Report of the U. S. Mining Commissioner for 1875, p. 116.

has been such that the bed of the old river is now one hundred or even two hundred feet above the surrounding country.

To work these deposits, careful surveys of the whole country must be made so as to be able to reach with a tunnel the lowest point of the bed-rock, which must be determined by sinking shafts upon it. The cost of this preliminary work may often be more than $100,000, and instances have been known where from want of proper judgment in the outset the whole of this sum has been lost. The location of the tunnel must be such that the pay dirt can be washed through it, and that it may form an outlet for all the material which is deposited after the extraction of the gold. Its construction involves the building of miles of sluices to catch the gold and carry the dirt away; the damming of streams to save the winter's water supply; the storing up of billions of gallons, and conducting it in ditches, flumes, and wrought-iron pipes, sometimes forty, fifty, or even a hundred miles in length, the ditches alone costing in some cases from half a million to a million of dollars, and involving constructions which are marvels of lightness, strength, and engineering skill. The following table[1] gives a fair idea of the size and cost of the ditches in California:

	Length Miles.	Capacity in Miner's Inches.	Grade. Feet per mile.	Size in Feet.			Cost.
				Top.	Bottom.	Depth	
Smartsville ditches....	......	5,000	9	8	5	4	$1,000,000
Eureka Lake and Yuba ditches...	163	5,800	....	....	....	.....	723,342
N. Bloomf'd ditches and reservoirs	157	3,200	12 to 16	8⅝	5	3½	708,841
South Yuba ditches............	123	7,000	3 to 13	6	....	4 to 5	....
Milton ditches and reservoirs....	80	3,000	12 to 15	6	4	3½	391,575
Spring Valley and Cherokee.....	52	2,000	....	5	....	3½	....
Hendricks	40½	......	6 to 12	5	....	2	136,150
Blue Tent.....................	32	18,000	10	8	6	4	150,000
La Grange....................	20	27,000	7 to 8	9	6	4	500,000

This water is discharged through iron nozzles with a velocity of one hundred and fifty feet per second, and at the rate, in some instances, of 4,220,000 cubic feet in twenty-four hours, against a bank from 250 to 300 feet high, and washes the earth into wooden sluices paved with rock or wood. To make the action of the water more effective, the bank is mined and fired, single blasts of from 1500 to 2000 kegs of powder being made.

[1] Burchard, "Production of Gold and Silver in the United States," p. 318. Washington, 1881.

As everything in the bank must come down, huge cranes with booms ninety feet long worked by hurdy-gurdy water-wheels are set up to lift the boulders,[1] under-currents[2] to catch the gold, grislies[3] to carry off the stones, drops[4] to break the materials up. The sluice itself has to be paved with stone or wood[5] and furnished with branches, so that one part may be repaired without detriment to the other. Every part must work harmoniously with the other parts, and must be adapted to the lay of the ground, and every possible resource in the surroundings made use of for its successful working. Individual enterprise could do little or nothing with such claims, but the constant and large returns show that the immense outlay is fully justified.

The gold is caught in mercury put into the sluices between the pavement and riffles. The greatest difficulty is not so much to catch the gold as to get rid of the tailings or material that has been treated. This involves the construction of miles of tail-sluices and the destruction of land and of streams by depositing on and in them stones and sand to great depths, but it saves for the use of the country the very large amounts of gold deposited in exceedingly small quantities in the ancient river-beds of California. No one who has not visited these mines can have any idea of the devastation produced by this washing away of hundreds of acres of surface and hundreds of feet in depth of the ground of these gold-bearing districts. It will be many years before this question of local devastation will need to be considered, but the filling up of the rivers and streams is engaging attention now.

The cost of producing one Troy ounce of metal is given below:[6]

	La Grange Co.	No. Bloomfield Co.
Water	$1.43	$2.09
Labor	6.85	3.93
Materials	1.81	0.88
Explosives	....	0.98
Blocks and lumber	....	0.50
General expenses	0.94	0.70
Contingent expenses	0.26	....
Taxes	0.09	....
	$11.38	$9.08

[1] *Engineering*, vol. 25, p. 58.
[2] *Engineering*, vol. 24, p. 487.
[3] *Engineering*, vol. 25, p. 20.
[4] Ibid.
[5] Ibid.
[6] The value of the metal was $18.53 per ounce.

The height of the bank washed down and the yield for several mines is given below:[1]

	Height of Bank in Feet.	Yield per Cubic Yard in Cents.
Smartsville Claims, Yuba Co.	112	19.5
Blue Tent, Nevada Co.	180	15
North Bloomfield, Nevada Co.	180 to 260	4 to 6.5
Gold Run, Placer Co.	200	4.8
Columbia Hill, Milton Co	100	4.33
La Grange, Stanislaus Co	18 to 100	2.5 to 15.5
Patricksville, Stanislaus Co.	40 to 60	4.33 to 18.5
Dardanelles, Placer Co.	150	13

The cost and yield per cubic yard of some of the mines is given below:[2]

	Cost.	Yield.
Roach Hill	$0.06	$0.60
Richardson	0.03	0.15
Iowa Hill	0.025	0.71
Independence	0.02	0.25
Wisconsin	0.02	0.125

The cowhide hose used at first soon became rotten and burst. This was succeeded by one made of heavy duck from four to ten inches in diameter. This was made sometimes of one, sometimes of two thicknesses. Such a hose will bear a pressure of fifty feet, but no more. To make it stronger it was surrounded by iron rings two inches wide and three inches apart, which were held in position by four ropes distributed evenly in the diameter. Such a pipe was called a crinoline hose, and would support a head of from 150 to 200 feet of water. This was subsequently abandoned for the sheet-iron pipe now generally in use. The profits of this kind of mining do not depend so much on the yield of the pay dirt as they do upon the cost of the water, the expense of getting rid of the tails, and the facility of working which depends on the lay of the ground. A claim well situated can work a much poorer gravel with a profit than one less advantageously placed.

TREATMENT OF GOLD QUARTZ.

As the placers grew poorer and the search for other sources of gold became active, the prospectors soon found gold in veins,

[1] Burchard, "Production of Gold and Silver in the United States," p. 318. Washington, 1881.

[2] *Engineering*, vol. 25, p. 59.

and these were then explored and worked. It was usually found in a hard rock which was ascertained to be quartz, but when it was afterwards discovered in other rocks no attention was paid to the correct name of the stone. The gangue of the gold was always called "the quartz," no matter how hard or how soft the rock was, or what its chemical composition might be; the "quartz," if it was quartz, was said to be hard, if it was slate it was said to be soft. To "get" the vein rock required capital and a much higher degree of skill than had as yet been required for the working of the shallow placers. Deep quartz mining could not be carried on by individuals, and mining companies were formed to mine the quartz and separate the gold. At first these were all undoubtedly legitimate enterprises, but it was not long before some men found or thought they found a more expeditious road to wealth in mining shares than in mining quartz—a practice which very soon brought discredit on all kinds of enterprises in the State of California.

To get the gold out of the vein-rock it had to be crushed. This was done in the very early days before mining companies were known, with a large rock bound to a pole supported on a crutch so as to have a long purchase. The rock was raised by one man and allowed to fall on the ore, while another kept the pieces of ore from flying away, with a stick of wood. It was not long before this rude Mexican hand labor was replaced by the arastra, which was a hearth or bed of uncut stones arranged in a circle from ten to twenty feet in diameter, with a curbing two feet deep on the inside, over which large stones were dragged by a single mule. It was necessary to run this machine for at least a week, and sometimes for two or even three times as long, to make it worth while to clean up. The joints between the stones were so open that the mercury and amalgam settled down between them so that the whole bed had to be dug up, the earth carefully collected and washed, and the hearth replaced before a new charge could be made. The hearth was then improved by making it of cut stones with very close-fitting joints laid in cement. To the upright part one arm or two arms at right angles to the diameter of the bed were placed, and to each end of the arms stones weighing from four hundred to five hundred pounds were attached by chains so that the forward end was about two inches above the hearth while the other end dragged on it. One mule was counted for each stone, so that there were one- or two-mule arastras. To make the charge for

an arastra ten feet in diameter, five hundred pounds of quartz broken by hand to the size of a pigeon's egg was put in, and the mules driven for four or five hours. Water is introduced to make a paste of the consistency of cream, and then quicksilver is added and the mule driven for two hours more. The paste is now thinned with water, the mule driven slowly for half an hour, the mud is run off, and another charge introduced. Four charges can be made in twenty-four hours, but two are generally all that are made, so that half a ton per day is about the limit of capacity of a ten-foot arastra. The clean-ups are easily and frequently made, so that this machine is a much better one than the first, which was built for very rude work.

It is quite easy to see from this description where the idea of pan amalgamation originated. It needs but a few mechanical appliances to be added to have the description of the pan as now used. The arastra is still a useful article, and as it costs next to nothing to erect, it may be used as a prospecting tool. The principle on which it is constructed is an excellent one, the grinding perfect. It gives a large percentage of the assay value, but is too slow for use where large quantities are to be treated.

The Chilian mill was used about the same time, and consists of a circular bed like the arastra, but the ore is crushed by two large circular wheels made either of stone or of cast-iron, which roll around on their edges. The methods used are the same. The machine is more expensive than the arastra, and does not do its work any better. It was not long before the eager and impatient miner found that the capacity of the arastra and of the Chilian mill was not sufficient for the profit which he wished to get out of his ore, and he looked to some of the crushing machines used in Europe to increase the capacity of his mill, and at the same time his hoped-for profit. The stamp-mill seemed the only one likely to be of use, and this was adopted. There were then but few mines whose output would justify the erection of stamps, but where it would do so they were built. In other cases the miners were obliged to depend either on the stamps of some neighboring mine being sufficiently at leisure to do other work than their own, or to mills being erected independently of the mines to do whatever work was brought to them. To distinguish such mills from the others they were called "custom mills." They work for everybody and at a fixed price, reserving the tails for themselves, which they usually take care should be rich.

The lumbering German stamp with its wooden stems eight inches square, its complicated and cumbersome cam shaft, and its inefficient mortar, was first built. Then some Cornishmen suggested the idea of the Cornish stamp, which, with its rectangular iron stems but inefficient mortar, was quickly put up, and was for a short time such an improvement that it was considered to be the *ultima thule* of crushing. This gradually grew into the rotating California stamp[1] and its adjunct the Blake's crusher, with its increased capacity and much better mechanical appliances, which is now almost exclusively used in California. The stamp with its head weighs from 500 to 1000 pounds. Its capacity is, for very hard rock one and a half tons, and for very soft rock four tons, in twenty-four hours. The average will be about two tons. It is built in batteries of five stamps each, so that each battery may be counted for ten tons in twenty-four hours—a capacity which, considering the cost, is very limited. It is in universal use in California, where no other means of crushing has been able to compete with it. In other parts of the country it has grown into the Ball's stamp,[2] a very large and heavy rotating stamp, in which the force of the blow is increased by the pressure of steam to such an extent that a single machine with one stamp-head is capable of crushing one hundred and ten tons of the hardest rock in twenty-four hours, and thus a single machine becomes equal in effectiveness to a sixty-stamp mill, which is the size of some of the largest mills in the West. No investigation has yet been made to ascertain the comparative efficiency of the use of power in these two machines. The Cornish, California, and Ball stamp are working side by side on Lake Superior, and it is to be hoped that experiments to settle the question of efficiency will be made. There are several other crushing machines which have lately been introduced, but none of them have been fully tested, tho some of them seem to be of great promise.

But it was not sufficient to crush the rock, the whole bulk of the crushed material had to pass over or through mercury in order to extract the gold and silver; and the quantity of this rock was so large that it produced losses in mercury so great as seriously to diminish the profits. Amalgamated plates and some free mercury were placed in the mortar, but this, unless

[1] "Stamp-Mills of California," *Engineering*, vol. 30, p. 19.

[2] *Metallurgical Review*, vol. 2, p. 285.

the pieces of gold were large, could never catch more than eighty per cent of it, and when the pieces were small not more than seventy per cent. If the gold is associated with silver as in some of the Nevada mines, but very little of it is caught there, and the amalgam so produced is so light and spongy that it is liable to be carried off; so that where gold ores contain much silver, lead, or antimony, battery amalgamation is unadvisable. There are many gold-mills where it is never used, tho some of the best conducted ones do use it. There must therefore be a sluice at the end of the splash-box to catch the fine particles coming from the mortar. The sluice is thus, as an appendage to the battery, as important as the battery itself. It serves a very different purpose from the placer-sluice, where the dirt is to be transported, the clay broken up, and the stones carried along so as to allow the gold to sink where the mercury is. The battery-sluice has neither to deal with stones, dirt, nor clay. It has to treat much less material; it is therefore much shallower and has a lower grade. When the ore contains copper and iron pyrites, these can by proper treatment be concentrated by it and saved. These battery-sluices are used with amalgamated copper plates with transverse riffles in which mercury is placed, and with the different kinds of blankets. Great attention is being given just now to iron riffles, not only for battery but for placer sluices. The experiments made give reason to hope for a great saving of the precious metals by their use wherever sluices are used. In some localities the battery-sluice is used in connection with such machines as the Attwood's amalgamator[1] and the Eureka Rubber,[2] but the tails are still rich. Some one suggested the use of cowhide with the hair on and the grain of the hair turned against the current, over which the tails were allowed to flow in order to catch the heavy materials, while the lighter ones were carried off by the stream; and out of this grew all the different styles of stationary and revolving blanket-sluices. Still the tails showed by assay that they were rich, and it was then found that the gold was contained in iron pyrites. It is very remarkable that at this period when Mexicans with their arastras and slow but extremely simple processes could make $50 to $60 a day, the best stamp-mills with the most efficient machinery, working on the same rock from the same vein could not recover

[1] *Engineering*, vol. 31, p. 247. [2] Ibid., p. 324.

from the ore more than $15 to $20. In some instances, with the best modern machinery an ore yielding by assay $700 to $800 in gold did not yield more than $20 to $30 when stamped and treated with the usual appliances. The slower but more perfect process of the arastra had brought the pyrites into such a fine state of division, and had by constant abrasion of the stone rubbed it so bright, that the "quick" took it up, while the more rapid process of the stamp did not. As soon as it was thoroughly understood that the pyrites contained the gold, concentrators of different kinds, with or without buddles or keeves,[1] were used to catch it, as no smelting process could be used in the localities where the pyrites was found, and the gold in the pyrites could not be separated with mercury.

The tails are therefore generally kept to be put through a series of concentrating machines whose object is to catch the pyrites and possibly some amalgam, but saves none of the gold which has escaped as float. It is a question of grave importance how this gold may be caught, or, better, how to prevent its getting into the condition in which it cannot be caught. The miners call the gold that escapes the mercury "float" and "rusty" gold. That some gold exists in the ore in such fine particles that it will float seems undoubted; against this there is no remedy. It is also true that the heavy stamp falling on the ore does make float-gold of some of the precious metal not in that state in the ore, but this is not the principal source of loss. If a piece of pure gold which amalgamates readily is pounded with a hammer on a smooth anvil, it is very soon put into the condition in which mercury will not touch it.[2] I have had such a piece of gold in contact with mercury for more than a week without amalgamation. From this condition the gold can readily be recovered in the laboratory, but it is doubtful if it can be saved in the mill. Something must be done to avoid it, as there seems to be no doubt that some part of the gold escapes amalgamation from this cause. But there is gold which is really rusty, not covered with a coating of oxide of gold, but of something which prevents contact with the mercury. Absolute contact is necessary to amalgamation, and the thinnest film between the two will prevent it. One of these coatings is oxide of iron, which does not occur very often and is very easily removed by abrasion, and

[1] *Engineering*, London, vol. 31, p. 404.
[2] *Trans. Inst. Min. Engs.*, Feb. meeting, 1881.

another is said to be silica; grease from the stamp, or which may be in the water used, will also produce it. I have shown also that a small amount of sulphuretted hydrogen or sulph-hydrate of ammonia will produce exactly the same effect, leaving an impalpable greasy film on the outside which prevents the action of the mercury. In other words, a dirty mill, water which is not clean and not carefully protected from drainage, will affect the gold. No one has until now thought it necessary to call attention to this subject.

I have elsewhere shown [1] that there are many other interesting facts relating to the metallurgy of gold which have escaped observation. How far they may affect its extraction from the ores is yet to be seen. It seems, however, certain that we are creating some of the difficulties, and that some other machine than the stamp will have to be used for pulverizing gold ores.

The cost of the treatment of a gold ore, including the mining, varies very much and depends on a great variety of circumstances, such as the hardness of the rock, cost of transportation, price of labor, etc. It may vary from one to ten dollars per ton. It is usually higher in custom mills than in those mills owned by the mine, where the quantity treated is very large. In such mills the cost of crushing, varying with the rock, will be from one to two dollars per ton. In the custom mill where only a small quantity is run it may be as high as five dollars for the same ore. The yield of the ore and the consequent profits are very variable. Ores yielding as low as five dollars have been treated in a large way with a profit, but so much depends both on the nature of the ore and on local circumstances, such as the management of the mill, that it is quite impossible to say how poor an ore could be worked. Perhaps no one thing has been so great a stimulus toward the perfection of the gold processes of California as the discovery of the mercury-mines there.[2] The demand for a large quantity of mercury so stimulated the rival companies that they improved their process to cheapen their production, and found themselves with such active competition that the price of quicksilver has fallen to less than one fourth of what it was, so that the free use of mercury is no longer feared in the poor mines, and the ominous question of the loss in mercury does not loom so high nor figure for so large a part of the cost in the processes as formerly.

[1] *Trans. Inst. Min. Engs.*, Feb. meeting, 1881.

[2] *Engineering*, vol. 28, p. 239.

For a number of years all the metallurgical losses of gold-mining were attributed to sulphurets, and processes for working these were invented without number, most of which have died out long ago. The beautiful process of Plattner[1] for roasting these sulphurets and then extracting the gold by chlorine was adopted and improved upon, and for a long time seemed to have solved the question, but little by little it was ascertained that there were certain substances contained in the gangue of the rock, such as lime and magnesia, and certain other substances which might be associated with the gold, such as lead and zinc, which would be attacked by the chlorine, and that there were circumstances in which after the gold was in a soluble form in the tanks it might be again precipitated in the insoluble material of the ore, and thus be lost. Recent experiments have been made with nascent chlorine with this gas under pressure, and other modifications which give promise for the future. It is apparent, however, that Plattner's process in any or all of its modifications does not cure all the evils, because it does not cover every variety of case, but is only applicable to certain ores in which there is nothing but the gold in the ore which would be attacked by the chlorine, and nothing which would prevent its acting on the gold.[2]

If the ore contained any silver this would be attacked, and a coating of insoluble chloride of silver would be formed over the gold; this would prevent further attack by the gas, and not only would the silver be entirely lost, but any particles of gold contained in it would also be lost. A very careful dressing might separate some of the gangue attacked by the chlorine, but it could never separate the whole, and any part of it remaining would be a source of loss; so that as a general rule it may be stated that when the ore contains anything but gold which the chlorine will attack, the process is not applicable. Besides, Plattner's process depends upon delicate chemical reactions. If, for instance, any of the sulphate of iron resulting from the roasting is left in the ore, as soon as the gold has been put into a soluble condition and is leached with water, a part of the gold dissolved is thrown down by the sulphate of iron. Certain organic compounds produce the same results. The gold thus previously rendered soluble is then precipitated in the

[1] *Engineering*, London, vol. 24, p. 119.

[2] Clay becomes diluted in the water. The earthy particles in suspension settle on the small flakes of gold and prevent the action of the chlorine.

filter of gravel on the bottom of the tub and is lost.[1] I saw such an accident at Grass Valley, and on examining the sand of the filter found it very rich in gold. It is not very wonderful, therefore, that a process which demands such nice working and depends on exact chemical reactions does not succeed very well where there are no trained metallurgists. I have known an expensive plant abandoned and the process brought into great disrepute for one of the reasons given above, when if there had been a trained metallurgist in charge there is every probability that the defect would have been remedied and the process would have succeeded.

It sometimes happens, too, that where the process is otherwise applicable, certain substances held in solution in the water of the district, if the gold already dissolved in the water is allowed to remain for a short time in the tanks, and sometimes by simply filtering through them, cause the gold already dissolved to be precipitated on the filter and thus to be lost. In some cases where the works might have been successful had there been only one, there were so many competing for the product of the district that they were obliged to lie idle more than half the time or pay a higher price for the concentrates than they were worth, in order to keep at work.

As a result of the knowledge that gold could be recovered from the tails, there followed a series of concentrating-machines, of blanket-sluices, of different kinds of amalgamators, of pans for grinding and amalgamating, and of single machines for doing a dozen things which require to be done each by a separate machine in order to be well done.

For a number of years the idea that gold and silver could be concentrated by means of smelting had not occurred to the people in the West. The miner had divided his ores into placer and milling ores, and the latter into free milling and rebellious, by which he meant ores which would or would not readily amalgamate. Such rebellious ores as would not yield to mercury after working, or to which some leaching process was not applicable, were treated for what could be got out of them. To make it possible to treat them by any other process to recover the gold, either copper or lead must be in such quantities that smelting will be remunerative. Such is usually the case to make the treatment for gold alone possible. It occurs in Colorado,

[1] *Trans. Amer. Inst. Min. Engs.*, Feb. 1881.

where a complicated European process[1] has been introduced with such modifications as were made necessary by local circumstances to treat ores of copper or lead containing gold, to which all the rebellious ores of the district can be profitably added; but the lead is always lost, while the copper is saved as a by-product. The gold thus concentrated in Colorado in a copper product is afterwards separated with little loss. If the gold is concentrated in a lead product, silver must be present, when the gold follows the silver and is afterwards separated from it.

Such methods of smelting are not common. Gold is not usually found in the United States in paying quantities in copper or lead ores, nor have those ores as a general rule been found in any very large quantities in the districts where rebellious gold ores occur, nor if they did, could the separation be undertaken except by men of great skill both in metallurgy and in financiering, as the failure of enterprises of this kind based on either the one or the other, but without both, has shown.

That gold associated with copper, lead, silver, and zinc could be separated by smelting when either lead or copper ore could be had in sufficient quantity, was learned after a long trial, but not until hundreds of thousands of tons of rich tailings from amalgamating processes, containing over four pounds of mercury to the ton in addition to large quantities of gold and silver, had been allowed to run to waste in the streams which flow down the cañons of the mining districts.

We cannot say that we have reached the utmost limit of metallurgical progress in the economical separation of the precious metals, for it has been ascertained that in the hydraulic mines, from which by far the larger part of the gold of California is produced, notwithstanding the great cost of their plant, not more than thirty-three per cent of the total amount of gold contained is saved.

The observer who takes the pains to calculate the millions of dollars contained in the tails which have been allowed to flow away looks aghast at these statistics, but the miner when he comes to consider them makes the very intelligent reply that while he gets out only thirty-three per cent he makes a profit for himself and his stockholders, but when he endeavors to save any portion of the other two thirds he makes either less profit

[1] *Trans. Amer. Inst. Min. Engs.*, vol. 4, pp. 285, 295.

or none at all, according to the amount of increase which he attempts to make. It is a matter of great regret to him that he cannot save the sixty-six per cent, but his regret is not that it is wealth lost which would be added to the wealth of the State, but that he cannot have it at the bottom of his own pocket; so he abandons it philosophically to the future miner with the expectation that nature will some time concentrate these tailings, or that some process will be invented by which the vast value contained in the tailings that are now lying piled up in many of the cañons of the West can be utilized. In the mean time the filling up of the river-beds[1] and the covering of some of the agricultural lands have become a serious political question, and it may be that in the near future California, which would probably not have been settled but by a mining population, will have to decide whether it will allow the agriculturist, who does not add nearly so much to the wealth of the State, to drive the miner out of the deep placer districts where he settled long before the farmer came there, since the granger element threaten proscription in the shape of legislation which compels the miner to retain his tailings in the side cañons and not to allow them to escape into the rivers or over the arable lands. This question has recently come into the courts of California by an injunction restraining the Miocene Mining Company of Butte Co. in that State, who own 1500 acres on Feather River of placers thirty feet deep, from discharging their tails into this river. The magnitude of the interests involved is shown by the following figures taken from the San Francisco *Alta* of June, 1881:

Miles of ditches and canals in the counties affected..	6,000
Number of men employed, from.................	5,000 to 10,000
" " Chinamen	500
Capital invested in the mines.....................	$150,000,000
Yearly product......................	$12,000,000 to $15,000,000
Mining population affected by the suit..............	130,000
Agricultural " " " " "	60,000

[1] The Tuolumne River in California was formerly five hundred feet wide and fourteen feet deep in the bed of the river, and had a fall of eighteen feet to the mile. In twenty-one months it was filled so that the water hardly ran over the river-bed. In 1875–6 the freshets washed the river clear, but since then it has been again filled, and is now only thirty-one feet wide and one foot deep. The Feather River fills up thirty feet in a single flood from these deposits, but scours itself free again, while the Yuba River at Marysville has filled permanently thirty feet, and fifteen miles above, one hundred and fifteen feet in thirty years.—*Engineering*, London, vol. 25, p. 20.

It is estimated that should this injunction prevail the amount of farming land now under cultivation which will be rendered valueless by the removal of the mining population will be equal in money value to the total amount of the value of the mining property involved. Should this injunction be made permanent, the State will probably learn too late that a valuable industry has been destroyed by people who found the mines working when they settled on the lands they occupy, and must have known beforehand what was in store for them in the near future. The industry so destroyed it will be difficult to re-establish, and it is very doubtful whether the State will be a gainer by it.

TREATMENT OF SILVER ORES.

As gold grew scarcer silver ores were looked for and became an object of great interest. At first only the rich outcrops of the free-milling lodes were worked, and the ores from them were treated by the old Patio processes which were found in Mexico, in which arastras and Chilian mills were used. Occasionally the Caso method was adopted by some person who had seen it at work or had heard of its working in Chili. The Caso method, working quicker than the Patio, was adopted in some places; the bottom of the box was replaced by iron, and then the sides, and then the idea of grinding suggested itself, until the amalgamation pan in all its varieties grew up little by little. It was at first thought that the pan could be used equally well for both grinding and amalgamating, and some persons still use it for both purposes. But it has been pretty well settled of late years that the machine can do only one kind of work well, and that any other kind of work forced from it is done at the expense of the yield.

The Freiberg barrel did not meet with much favor in the West. Most of the emigrants of 1848 were of Anglo-Saxon origin, and when the German came with his slow but certain methods, a few mills adopted the barrel. But in the early days quick returns were demanded. The pan was an American invention. It moreover had grown on "the coast,"[1] and every one knew or thought he knew how to use it. Every machine-shop was ready to make it, and was more or less interested in one of the many patents taken out for a new one. It gave a return in from three to five hours, while the barrel worked twenty-four before the

[1] All the Sierra Nevada district is called "the coast" in the West.

amalgam was extracted. The pan required nothing but the ore, mercury, "the chemicals," and water. These had to be used in the barrels, and in addition some iron. Balls were used at first as in Europe, then pieces cut from stamp stems, and then mule and horse shoes, and finally anything made of iron whether adapted by its shape to the purpose or not. The result was imperfect, partly from the want of material adapted to the purpose, and partly because it was not always possible to get the material wanted in a given time. The consequence was that most of the mills that put up barrels found no one to run them, or were obliged to keep one set of men to run and another to repair them. Yankee wit did improve them so as to make each barrel independent by using friction clutches, and by doing away with the cogging by the substitution of friction gear; but a change in the administration usually threw the barrels out and put in the pans, so that the barrel, while everywhere condemned in favor of the pan, has really not been fairly tested. It is cheaper to erect and cheaper to run, but slower in action, and with friction gear ought to compete with the pan.

Amalgamation whether in the barrel or the pan was first used only for ores that are now called free-milling—that is, which will amalgamate immediately with the mercury. But it became evident soon that there was a large amount of ore which would not amalgamate. It contained sulphur and other substances which either prevented the action of the mercury altogether or caused a great loss of it. Such ores were called rebellious, and at first were not used; afterward they were roasted, the principal object of the roasting being not only to drive off the sulphur which was present, but by adding a little salt to convert the silver into chlorides which could be easily attacked by the mercury, which process was called the Reese River Process in distinction from the Washoe, which is the free-milling.

Up to this time stamping had generally been done wet in order to avoid the losses occasioned by the dust, as there was no reason why in the Washoe process the wet ore should not be delivered to the pans as soon as it settled sufficiently to form the "pulp," but with rebellious ores in regions where fuel was generally scarce, too much heat would have to be used in driving out the moisture from the ore,[1] and dry-stamping took the

[1] "The Stamp Mills of California," *Engineering*, London, Eng., vol. 31, p. 246.

place of the wet. As the ore came from the mine damp, drying floors, made by running the flues of the roasting furnace backwards and forwards under the iron plates covering the floors behind the stamps, were used, and the ore from the mine was spread out over these plates until it was dry. As there was nothing but the force of the blow from the stamp-head to deliver the ore from the screens, the operation was slower, and as no water current carried the ore away from the front of the stamps, endless chains were placed in the dust-tight boxes which enclosed the front of the mortar-screens, which delivered the crushed ore into bins in the roof of the works, whence it was delivered by spouts into the furnace.

Every kind of furnace for roasting was invented and tried. These were usually some kind of reverberatory furnace, and were the subject of a large number of patents, and were altered and modified with more or less permanent success. Attempts were made to make the work wholly mechanical by the use of revolving cylinders into which the ore and salt were charged by machinery, in order to get rid of the difficult hand labor required, and the necessary exposure to fumes in roasting in ordinary reverberatory furnaces. A few of these survive in the Bruckner[1] and Teates furnaces, but as a general thing the cost of repairs to these contrivances, and the necessity of more engine-power or of separate engines in the absence of machine-shops near at hand, increased the expense of working beyond the gain in diminished labor.

On account of the large loss both in mercury and in silver which are carried off in the tails, mills[2] called tail-mills have been erected, where, notwithstanding the large loss in mercury which is known to exist in the treatment, there is a constant increase in the quantity of mercury, and very often a large yield in silver. These mills have no work to do unless the tails are accumulated by damming the valleys through which the tail-streams pass. When the accumulated tails have been treated, the mills have no further use, and very often the heavy freshets do the work first by sweeping the tails away. Sluices of great length and width have been put up, but their tails are still rich.[3] Many machines have been invented for catching mercury and amalgam by making the tails pass over revolving blankets, rub-

[1] *Engineering*, vol. 22, p. 575.

[2] "Treatment of Tailings," *Engineering*, vol. 30, p. 395.

[3] *Engineering*, vol. 30, p. 395.

bers, revolving amalgamated plates, and many other contrivances, but they are not as yet successful in the commercial sense.

When lead, copper, or zinc were present in the ores in any considerable quantity they became so rebellious that amalgamation was out of the question, and smelting, with its necessary adjunct of concentration, became necessary. As the dressed ores were rich and contained a large product condensed into a small one, and as this product was usually sold, sampling[1] works sprung up, in which the value of a large quantity of ore was carefully ascertained by processes more or less mechanical, in which, as rapidity of execution as well as correctness of results were necessary, a number of tools for reducing the ore to powder now generally used were invented.[2]

The first attempts at smelting, as they were usually conducted by persons of no great experience, were not very successful. In fact, the early history of the now very successful American methods is a record of failures. When the smelting of silver ores became a necessity, English methods were first introduced by the Cornish miners, only a few of the German and Swedish furnaces being used. But as the English type of furnace requires a considerable amount of good fuel, of a kind not generally found in the West, and the use of wood in them requires great skill, shaft furnaces gradually took their place, for the most part for treating ores containing gold, copper, silver, and lead by smelting.[3] Some of the processes adopted from the old works in Europe found themselves in circumstances where the conditions of transportation, labor, or fuel were such that they could not compete with other districts, so that they gradually disappeared, and were succeeded by the same processes in a new dress or in a new phase to such an extent that the plant and the process as it is now used in the West would hardly be recognized by their inventors. Little by little it was ascertained that when the ore contained any volatile material, although it might be in small quantities, it would carry off with it very considerable portions of the precious metal; and then arose the idea of condensing chambers, until gradually, without any one person having invented them, the methods have grown into the simple and very beautiful processes which are now in use in the West.

[1] *Engineering*, vol. 22, p. 495.

[2] *Engineering*, vol. 22, p. 495, figs. 5 to 12.

[3] *Transactions of the American Institute of Mining Engineers*, vol. 4, p. 275.

At first the only fuel used was charcoal, and this, as wood was scarce, was sometimes made from dead or from float wood, or from woods too light for the purpose, so that it very often happened that the charcoal would crush by its own weight, and would not stand a charge in the furnace at all. It then became evident that the ores must have a comparatively high yield, and that as they usually had a gangue composed for the most part of silica, coke was necessary, and this, with from ten to twenty per cent of ash,[1] was imported from the East or from Europe at an expense in some of the works of forty dollars a ton. As it became evident that coke was the necessary fuel, it also became apparent that something must be done to reduce its cost, and also the cost of the refractory materials. Water-back furnaces were then introduced, which consisted of cast or sheet iron boxes riveted together, surrounding the hottest part or the whole of the furnace and cooled with water. These furnaces were for the most part open-breast furnaces with front hearths, and were continually getting out of order from the formation of sows and bears which occasionally stuck to the bottom or formed engorgements in the furnace higher up. To avoid these the Ahrent's tap was invented, which keeps a very considerable quantity of lead on the hearth of the furnace at all times, and allows of the casting being done without interfering with the interior. In other works where copper is in large quantity the ores are smelted for copper, and the silver and gold concentrated in one of the products, from which it is separated in the wet way by the skilful adaptation of old processes.[2]

It now became evident that there were considerable mechanical losses from the metal being carried up and out of the chimney, so that in some instances in Utah as much as ten or even fifteen or twenty per cent was carried off in this way. Attempts were then made to collect this material as is done in Europe in condensation chambers of large size and extent, and several systems of doing it have been invented. The simplest, the cheapest, and the most recent of these is used at Mansfield Valley, near Pittsburgh, Pennsylvania,[3] and is an adaptation of the flue leading to the chimney by dividing it in two sections vertically. In the lower one of these, partitions eighteen inches high, placed

[1] The high percentage of ash in the coke has in several instances caused the failure of works which with a suitable fuel might have been successful.

[2] *Trans. Amer. Inst. Min. Engs.*, vol. 4, p. 276.

[3] *Annals N. Y. Acad. Sci.*, vol. 2, p. 106.

four or five feet apart and one third of the height of the flue, catch the dust by gravity, and as there is no velocity below, it remains there. The gas circulates above.

Generally the silver and the gold in a district where lead ores can be had, are concentrated in a pig lead improperly called "base bullion." In some few cases in the early days the German method of cupellation was used, but as this requires a maximum consumption of fuel, great skill, and a market for litharge, it was quickly superseded by the English method, which requires less skill, makes no litharge for sale, but required the poor lead to be concentrated into a rich one and that treated for gold and silver. The Patterson process by crystallization for enriching the lead previous to cupellation was never extensively used here, principally because at the time when there was a large amount of work to be done the process had already been superseded. The lead directly from the furnace is now enriched by zinc desilverization,[1] and the rich lead cupelled in an English furnace.

The history of this process is very peculiar. Invented in 1842 by Karsten, it was declared a failure after a prolonged investigation by that very able metallurgist. It was reinvented by Crooks in 1858 in England, where it was not very successful, and was brought to this country as an English process. It was tried again at Tarnowitz, in Silesia, and was more or less of a failure there, and was then reintroduced into this country, and so many improvements made in it that to-day the American modification of it has become the perfection of a process, and the furnace used a type furnace.

In order to use the method of desilverization by zinc it is necessary that the lead should be very pure. To purify the lead small refining furnaces were used in Germany, containing two to three, and subsequently from five to six, tons each. But in this country one of the first improvements made was the softening or purification of the lead in a furnace containing from fifteen to twenty, and subsequently as high as twenty-six tons; but as the hearth of such a furnace was difficult of construction, it was simply made in a cast or wrought iron pan. This softened lead had to be discharged from the furnace, which was not an easy matter, and the late Mr. Steitz

[1] *Annals N. Y. Acad. Sci.*, vol. 2, p. 86.

invented a siphon[1] to do it, which seemed to be the perfection of an instrument for this purpose.

The refined lead is stirred with zinc, the zinc-scums carrying the silver with them are liquated to separate the excess of lead, and the result is a very rich zinc alloy, containing a large amount of lead, which is granulated and distilled in retorts. The distillation in retorts promised at one time to wreck the process, as it had to be effected in small furnaces[2] surrounded by coke, and the number of retorts broken was large, notwithstanding the use of Steitz's siphon. Petroleum was then tried with great success lessening the breakage of the retorts due to the charging of the fuel and the poking of the fire. Subsequently Mr. Faber du Faur invented his tilting furnace, which allows of pouring the rich silver lead out of the retort without disturbing it, thus removing all the difficulty. The silver lead from which the zinc has been distilled is cupelled in an English furnace and cast into pigs. The lead from which the silver has been removed is refined in a furnace similar to the softening furnace, called a calciner. All the lead so refined is of the highest quality fit for the manufacture of white lead. It is produced almost as a by-product, and at a low cost.

The improvements in cupellation have been, first, the invention of the iron cupel surrounded by water, by the late Mr. Steitz, of St. Louis, upon which the lead could be brought up to fine silver, and the later invention of Mr. Eurich, of the Pennsylvania Lead Company, of going from the lead riches to silver 996 fine, on a hearth made of Portland cement, and casting directly from the cupel into silver bricks by a simple arrangement for tipping the cupel.[3]

It sometimes happens that silver can be extracted from its ore in the wet way. There are three principal methods which have been used for this purpose. The first was introduced in 1849 by a German named Augustine, and consists[4] in transforming the ore into chloride by roasting the ore to drive off the sulphur and other impurities, grinding the roasted ore and then roasting with salt to form chlorides; then dissolving out the chlorides with a saturated solution of salt, precipitating the silver with copper, compressing and melting the silver. It is

[1] *Annals N. Y. Acad. Sci.*, vol. 2, plate 7, fig. 6; plate 9, fig. 10.

[2] Ibid., p. 98.

[3] Ibid., p. 108.

[4] *Trans. Amer. Inst. Min. Engs.*, vol. 4, p. 295.

usual to concentrate the silver into copper mattes for this process. Shortly after the invention of this process, another, much simpler, was invented by Ziervogel,[1] which consists in roasting mattes to produce sulphates, decomposing all these sulphates except that of silver, and then dissolving out the sulphate of silver with hot water. Simple as it appears, this process is exceedingly difficult to execute, for it requires a very high degree of skill to seize the exact moment when all the sulphates of the other metals are decomposed and none of the silver is. If the sulphates are not all decomposed the silver is precipitated by them; if they are, there is danger that the silver sulphate also will be decomposed, and it will then be lost, as the oxide is not soluble. The practice, therefore, is to leave a little of the sulphates of these metals undecomposed, as the loss in this case can be calculated beforehand, while no one can tell what it will be in the case of too much roasting. As these residues are always rich, they are often treated by the Augustine process, the two being very advantageously used together in this country.[2]

In looking at the silver process as a whole and comparing the cost, we find that the relations between the relative cost and quantity of silver extracted were very interesting.

	Relative Cost.	Relative Loss.
Amalgamation	2.2	2.0
Augustine process	1.8	2.0
Ziervogel "	1.0	1.0

The Ziervogel process is, both as to cost and residues, twice as advantageous as the others.

Still another process was invented in 1858 by an Austrian of the name of Von Patera, which consists in roasting, as in the Augustine process, leaching with hot water before roasting with salt in order to dissolve out any soluble salts, roasting with salt, then dissolving the chlorides with hyposulphite of soda, precipitating the silver with polysulphite of sodium, and then reducing the sulphide of silver. This process is easily carried out, in that the reagents can readily be had, and that none of them are wasted; but both the lixiviation and the precipitation require such nice distinctions and such an exact chemical knowledge that it has not been very successful.

The bullion which is produced as the result of treatment of any of the ores usually contains some small quantity of the

[1] *Trans. Amer. Inst. Min. Engs.*, vol. 4, p. 245. [2] Ibid., p. 295.

base metals besides the gold and silver. The gold from California generally contains about twelve per cent of silver, that from Australia four to six per cent. The amount varies from three per cent to about twenty-five per cent. The silver bullion often contains gold, as in the case of the Comstock, where one third of its value is gold; and these metals must be separated in order that they may be alloyed to their proper standards for commercial uses. Neither pure gold nor pure silver is of any use commercially except for electroplating; for all other purposes they would be much too soft. The process of separation is called parting. To effect this an alloy is made by melting, which usually contains three parts of silver to one of gold. In a single instance in California this alloy is three of silver to two of gold. The formation of this alloy is called quartation or inquartation. It is granulated and subjected to one of three different processes; the silver is dissolved out by either nitric or sulphuric acid, and in both cases the residue not dissolved will be gold. The nitrate of silver siphoned off from this is diluted with water and precipitated with salt. The chloride of silver so formed is reduced to a metallic state with sulphuric acid and zinc, and the silver melted into bars whose fineness is stamped on them, and they are then used for commercial purposes. In the case of sulphuric acid, sulphate of silver is formed, which is diluted with hot water and precipitated as metallic silver by copper. The spongy silver is pressed into cakes by a hydraulic press and melted into bars. The gold is collected, melted, and run into bars. The nitric acid method has been generally abandoned, because it poisons the neighborhood with fumes. The sulphuric-acid process, which is a little cheaper, has taken its place, except in California, where a very beautiful method, invented by Mr. Gutzkow,[1] has taken its place. This method, which is very ingenious, much quicker and gives better results than the others, was introduced in San Francisco in 1867. Most of the alloys are not granulated; they are inquartated and dissolved in sulphuric acid, in bars. The sulphate of silver is crystallized and a solution of sulphate of protoxide of iron run through it, which reduces the silver to a metallic state; the iron solution becomes sulphate of sesquioxide of iron, and is restored to its original condition with fresh iron and used again. The silver is pressed and melted as before,

[1] Burchard, "Production of Gold and Silver.' Washington, 1881, p. 356.

and the gold from the pots treated in the same way. This process is not only very simple, but is in a chemical way one of the most beautiful known.

The amount of silver produced in the United States previous to 1858 was so insignificant that no statistics have been recorded. In that year it was only $500,000; in 1859 it was only $100,000; in 1860 it was $150,000; but in the following year, 1861, the amount of silver began gradually to increase, until the year 1870, when it was $16,000,000. The total amount produced in this decade from 1860 to 1870 was $84,300,000, the lowest amount being $150,000, in 1860. From 1870 to 1880 the amount of silver becomes a very considerable factor in the world's production of this metal, the highest amount being a little over $45,000,000, in 1878, and the lowest $16,000,000, in 1870, the total production for the decade being $374,922,260. If these amounts of silver are added to the amounts of gold shown in the table, in the last number of the QUARTERLY, p. 80, it will be seen that for the decade from 1860 to 1870, the highest production of precious metals was in 1869, $61,500,000, and the lowest was $43,700,000, in 1862, the total being $555,150,000. For the next decade, from 1870 to 1880, the highest production was in the year 1878, $96,487,745, and the lowest $66,000,000, in 1878. The largest amount of silver produced by any one State during the year 1880 was $17,000,000, obtained in Colorado, and the next largest $10,000,000, from Nevada.

YEAR.	Silver.	Total Gold and Silver.	YEAR.	Silver.	Total Gold and Silver.
1858........	$500,000	$50,500,000	1870.......	$16,000,000	$66,000,000
1859........	100,000	50,100,000	1871.......	23,000,000	66,500,000
1860........	150,000	46,150,000	1872.......	28,750,000	64,750,000
1861........	2,000,000	45,000,000	1873.......	35,750,000	71,750,000
1862........	4,500,000	43,700,000	1874.	37,324,594	70,815,496
1863........	8,500,000	48,500,000	1875.......	31,727,560	65,195,416
1864........	11,000,000	57,100,000	1876.......	38,783,016	78,712,182
1865........	11,250,000	64,475,000	1877.......	39,793,573	86,690,963
1866........	10,000,000	63,500,000	1878.......	45,281,385	96,487,745
1867........	13,500,000	65,225,000	1879.......	40,812,132	79,711,990
1868........	12,000,000	60,000,000	1880.......	37,700,000	73,700,000
1869.... ...	12,000,000	61,500,000			

Such enormous productions of the precious metals have not been without their influence on the relative value of gold and silver in other countries. The United States is one of the largest producers of the precious metals, notwithstanding, as the statis-

tics show, there has been a gradual falling off in the production of gold, and the highest limit of silver appears to have been in the year 1878, since which time the decrease in the production of the Comstock has brought down the production of silver from its maximum in 1878, nearly $8,000,000, and it seems likely that this decrease will continue.

The amount of gold consumed in the United States for purposes of art and ornament during the year 1880 was larger than for several previous years. The following table from the Report of the Director of the Mint, which is a mine of information for those interested in the production and distribution of the precious metals, gives the returns of the New York Assay Office for that year:

BARS MANUFACTURED.[1]

	Gold.	Silver.	Total.
From United States coin (defaced).........	$4,929	$982	$5,911
Foreign coin............................	260,222	72,668	332,890
" bullion........................	1,007,400	278,622	1,286,022
Domestic "	2,988,422	3,863,126	6,851,548
Plate, etc....	394,871	144,992	539,863
Total.......................... ...	$4,655,844	$4,360,390	$9,016,234

From the whole United States this amount is much larger; but leaving out the foreign bullion altogether, the following table gives the estimate of the total gold and silver used in the whole United States for industrial purposes during the last year:

	Silver.	Gold.
Domestic bullion...................... ...	$4,000,000	$5,000,000
U. S. coin..............................	600,000	2,500,000
Plate, foreign bullion, and coin.	400,000	2,500,000
Amount consumed......................	$5,000,000	$10,000,000

The consumption of the precious metals for purposes of art and ornament has been the subject of estimates by many distinguished statisticians, but at the best can only be approximated. In 1827 Humboldt placed it at 375,000 ounces, or one fifth of the world's production at that time. In 1822 Lowe estimated it at two thirds. William Jacob estimated it at 988,000

[1] Report Director of the Mint, 1880, p. 19.

ounces, which was double the average annual production between 1821 and 1830. Dr. Soetbeer, of Germany, gives the following tables of the consumption of the precious metals for jewelry and other industrial purposes in the various countries of the world:[1]

GOLD.

	Consumption, in Ounces.	Reduction by Old Material used.	Total Consumption.
United States	529,000	10 per cent	476,000
Great Britain	703,000	15 "	598,000
France	739,000	20 "	591,000
Germany	518,000	20 "	412,000
Switzerland	529,000	25 "	397,000
Austria	102,000	15 "	87,000
Italy	212,000	25 "	159,000
Russia	106,000	20 "	85,000
Other Countries	176,000	20 "	141,000
Total	3,614,000		2,946,000

SILVER.

	Consumption, in Ounces.	Reduction by Old Material used.	Total Consumption.
United States	4,233,000	15 per cent	3,789,000
Great Britain	3,175,000	20 "	2,540,000
France	3,528,000	25 "	2,646,000
Austria-Hungary	1,411,000	20 "	1,129,000
Switzerland	1,129,000	25 "	847,000
Italy	882,000	25 "	662,000
Russia	1,411,000	20 "	1,129,000
Germany	3,528,000	25 "	2,646,000
Prussia	1,870,000		1,411,000
Total	21,167,000		16,799,000

Other estimates give the entire consumption of the precious metals in Europe and America for industrial purposes in 1880 as from $45,000,000 to $55,000,000 in gold, and from $25,000,000 to $30,000,000 in silver.

From 1831 to 1880 the estimated consumption of gold for industrial purposes was 73,000,000 ounces, or 32.6 per cent of that produced. For silver it was 511,000,000, or 25.2 per cent.

Of the world's product of bullion it is estimated that one third is used up and lost in the wear and tear of coins and articles made for use or ornament, one third is used for manufacturing purposes, and one third goes to supply the increased de-

[1] *Engineering and Mining Journal*, vol. 32, p. 183.

mands of trade. The amount lost by the abrasion of coins is shown by the fact that the average life of an English sovereign is eighteen years, by which time the coin has lost three quarters of a grain and is no longer legal tender. Dr. Soetbeer[1] states that the annual loss from this source in civilized countries reaches 28,000 ounces of gold and 1,600,000 ounces of silver.

The following table[2] shows the amount of gold and silver produced in the world in the years 1877, 1878 and 1879:

	1877.		1878.		1879.	
	Gold.	Silver.	Gold.	Silver.	Gold.	Silver.
United States	$47,897,390	$39,793,573	$51,206,360	$45,281,385	$38,899,858	$40,812,132
Russia	27,226,668	467,844	27,967,697	448,016	26,584,000	415,676
Australia	29,018,223	...	29,018,223	...	29,018,223	...
Mexico	996,898	27,018,980	996,898	27,018,940	989,161	25,167,763
Germany	204,697	6,135,877	205,361	6,938,073	205,361	6,938,073
Austria	1,196,278	2,119,948	1,196,278	2,161,515	1,062,031	2,002,727
Sweden	2,658	54,038	6,001	52,708	1,994	62,435
Norway	...	188,052	...	166,270	...	166,270
Italy	72,375	17,949	72,375	17,949	72,375	17,949
Rest of Europe	...	2,078,380	...	2,078,380	...	2,078,380
Argentine Republic	78,546	420,225	78,546	420,225	78,546	420,225
Colombia	4,000,000	1,000,000	4,000,000	1,000,000	4,000,000	1,000,000
Rest of S. America	1,993,800	1,039,190	1,993,800	1,039,190	1,993,800	1,039,190
Japan	265,840	706,649	295,746	728,846	466,548	916,400
Africa	1,993,800	...	1,993,800	...	1,993,800	...
Total	$113,947,173	$81,040,665	$119,031,085	$87,351,497	$105,365,697	$81,031,220

Dr. Soetbeer[3] gives the totals as:

1877.		1878.		1879.	
Gold.	Silver.	Gold.	Silver.	Gold.	Silver.
$121,514,026	$96,855,376	$122,058,368	$104,126,608	$104,245,987	$102,229,521

These tables show that the United States is by far the greatest producer of the precious metals, Russia being the only one which produces anything like as much gold, and Mexico the only one that approaches it in silver.

The amount of precious[4] metals sent to the East, the greater part of which goes to India, has been estimated by Dr. Soetbeer as:

	Gold, in Ounces.	Silver, in Ounces.
1831–1840	35,000	7,750,000
1871–1880	423,000	38,000,000
1831–1880	19,700,000	1,376,000,000

In the period from 1871–1880, which is most reliable, the consumption of gold by this means was 47,000 ounces, and of

[1] *Engineering and Mining Journal*, vol. 32, p. 182.

[2] Report Director of the U. S. Mint, 1880, p. 159.

[3] *Engineering and Mining Journal*, vol. 32, p. 182.

[4] Ibid., p. 183.

silver 4,200,000 ounces. In India alone the imports in the last forty years have exceeded the exports of these metals by $400,-000,000, of which only $8,000,000 have been coined as money.

The amount of the precious metals hoarded or put out of circulation either as objects of art or ornament is becoming greater with every decade. It appears from the data given page 167 that the total annual consumption of the precious metals for purposes other than coinage is about 3,600,000 ounces of gold and 21,000,000 of silver. It has been estimated that the entire amount of gold now in the world is only equal to that which has been produced in the last twenty-five years, and that of silver to that produced in the last eighty years. No one has as yet been able to satisfactorily explain what has become of all the rest of the precious metals.

Only an estimate can be made of their wear and tear, which is an irretrievable loss, either in the abrasion of coin or in the use of leaf or of the pure metals for plating purposes. Add to this the amount lost in lead, copper, and other metals, which do not contain enough of it to separate, and it is not a matter of surprise that, notwithstanding the enormous yearly increase, the estimate of the total amount supposed to exist in the world during any period is not perceptibly greater.

In all the methods for the extraction of the precious metals there are considerable losses. With the perfection of processes, the main object is to reduce them, or else to cheapen the labor of extracting the ores. These losses are greater than is usually supposed, because as a general rule systematic assays of the tails are not made. Yet it is known that the tails contain precious metals, and they are sometimes re-worked with profit, especially those from the silver mines. An interesting investigation was made some years ago, the results of which are given below,[1] showing the great loss in some of the mills.

	Yield of Ore in the Mill.	Remaining in Tails.		Total in Tails.
		Gold.	Silver.	
At the mill	$18 60	$10 04	$3 14	$13 18
Same tailings 350 ft. from mill	18 60	5 02	3 92	8 98
Average yield of 150 tons	3 50	13 55	6 28	18 83
" " "	3 50	8 79	6 28	15 07
Slime from end of sluice 310 ft. long		56 00	33 30	89 00

[1] Report of the U. S. Mining Commissioner, 1872, p. 17.

It was also found that water from the mills three fourths of a mile below them contained in suspension, as an average of twelve assays, \$0.018 per gallon. There were in this locality 576,000 gallons of this water flowing away in twenty-four hours, or a loss of \$339.84. It was estimated that the annual loss of two mills working 250 days in the year was \$84,960. From these and similar data the conclusion is drawn, that the loss is between fifty and sixty per cent of the total yield of the ore.

It is a matter of great interest to ascertain what the cause of these losses is, in order to learn how far they are capable of remedy. The first of these is undoubtedly a desire to get the largest possible output from the mill. This makes the ore too coarse to have all the gold and silver amalgamate, as part of it may not be released from the gangue. It would be much better to get the output by a more careful sizing of the ore, not forcing the stamp to do the work of a Blake's Crusher, and not sending to the mortars any ore fine enough to pass the screens. This is a matter of some importance, for it has been found with all kinds of stamps using screens, that it takes just as long to get crushed ore which has already passed the screens out of the mortar, as it does to crush and force it out. Too fine crushing is also quite as bad, for it produces "float," and is quite likely to put the precious metals in a condition in which they will not amalgamate.

Supposing that the losses which result from improper working do not exist, there are a few causes of loss which do not always amount to much, but which, in the early days, were a source of considerable loss. It has been found that any holes in the castings of the stamps, pans, etc., will attract the amalgam, and that it will even be carried into holes deep in the interior of the piece. This was a source of profit in the early days to those who recovered the precious metals when the worn out castings were melted. Another loss may be in cleaning the plates by taking off the amalgam too thoroughly. It is a well-known fact that new plates do not act as readily as old ones; the difference is so great, that when the mills can afford it, new plates are coated with gold or silver amalgam. Gold and silver will go much quicker to amalgam than to mercury. Too slow a current of water will keep the surface of the plates covered with a film of sand; a too rapid current will prevent the gold from being caught. If the gold is attached to a piece of the gangue rock which is relatively large, the specific gravity may be so reduced as to prevent the particles from coming in contact with

the mercury. If the blankets are left too long without washing, so that the hairs become charged, the fine particles of gold are lost. If all these causes of loss are avoided, there are still others. For if the mercury is not kept clean or made so by chemicals, the "quick," having an extremely thin film upon it, does not act upon the gold or silver. Exactly the same effect is produced to a small extent when the rock is soapy, as is the case with some of the magnesian and aluminous rocks. If there are too few amalgamating machines, if the sluices are too short, there is also a loss. A very important source of loss is the flouring of the mercury from too rapid motion, or from the too free use of chemicals. In such cases steam may be used, if it is live steam fresh from the boiler, which prevents flouring by the expansion of the globules. If steam from the engine is used as a matter of economy, it often increases the loss, as very minute particles of grease are always carried off with it, which coat the mercury. The cause of the losses on the concentrates has already been discussed.